I. C. 7010

April 1938

UNITED STATES
Department of the Interior
Harold L. Ickes, Secretary

BUREAU OF MINES
John W. Finch, Director

INFORMATION CIRCULAR

# ADVANCED MINE RESCUE TRAINING COURSE OF THE BUREAU OF MINES

RECEIVED
MAY 31 1938
O. S. U. LIBRARY

BY

**J. J. Forbes**

---

**After this report has served your purpose and if you have no further need for it, please return it to the Bureau of Mines, using the official mailing label on the inside of the back cover.**

I.C. 7010,
April 1938.

INFORMATION CIRCULAR

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

---

# ADVANCED MINE RESCUE TRAINING COURSE OF THE BUREAU OF MINES[1]

By J. J. Forbes[2]

## CONTENTS

| | Page |
|---|---|
| Introduction | 1 |
| Development of American breathing apparatus | 2 |
| Regular mine rescue training course | 3 |
| Need for advanced training | 4 |
| Advanced mine rescue training course | 4 |
| Advanced training in mine rescue and recovery operations for coal-mine fires and explosions | 5 |
| Publications | 9 |
| Mine explosions in the United States | 10 |
| Conclusions | 10 |
| Acknowledgments | 10 |

## INTRODUCTION

The activities of the Bureau of Mines include the development and testing of self-contained oxygen breathing apparatus and other devices for respiratory protection, the development and testing of devices for detecting dangerous or noxious mine atmospheres, and the training of men in the mineral industries in the use and care of this equipment to enable them to render effective service in mine rescue and recovery operations following mine fires and explosions, or under other conditions where irrespirable gases may be found in mines or mining plants.

The first use of self-contained oxygen breathing apparatus for combating mine fires and explosions in the United States dates back about 30 years. Previous to that time, exploration for any distance ahead of fresh air was virtually impossible without great risk to life; moreover, the men called upon to render service at mine disasters were not well-versed in the properties and physiological effects of gases likely to be encountered. It was also impossible to work ahead of fresh air to restore ventilation, and if many stoppings were blown out by an explosion, air had to be introduced into whole areas or sections at once without knowledge of the conditions ahead; moving an explosive mixture of methane and air over live fire had to be risked to recover the mine. Needless to say, many men lost their lives through lack of proper respiratory equipment, through lack of knowledge of mine gases and their properties, and through lack of experience with safe and systematic procedure. Today rescue and recovery operations can be conducted with reasonable safety, provided that proper equipment, in good condition, is supplied to well-trained men under experienced supervision and that modern procedure is followed.

---

[1] The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7010."

[2] Supervising engineer, Safety Division, Bureau of Mines, Pittsburgh, Pa.

According to available records, it seems probable that the first self-contained oxygen breathing apparatus was installed in this country in October 1907 at Butte, Mont., at the mines of the Boston & Montana Mining and Smelting Co. (which later became part of the Anaconda Copper Mining Co.). During May 1908 three sets of apparatus were obtained by the Pittsburgh & Westmoreland Coal Co. in western Pennsylvania; in September 1908 equipment was purchased by the Technologic Branch of the United States Geological Survey (which later became part of the Bureau of Mines), and in October 1908 the Lehigh & Wilkes-Barre Coal Co., of the Pennsylvania anthracite region, installed self-contained oxygen breathing apparatus. All of this equipment was of the Draeger type, manufactured in Germany.

According to the records, the first actual use of self-contained oxygen breathing apparatus during a mine fire was at the Minnie Healy mine of the Boston & Montana Mining & Smelting Co. at Butte, Mont., in October or November 1907. The first actual use of such equipment after a mine explosion was at the Monongah mine of the Consolidation Coal Co., Monongah, W. Va., where a representative of the Technologic Branch of the United States Geological Survey and a representative of the Draeger Co. made several explorations ahead of fresh air in December 1907.

The first training in the use of self-contained oxygen breathing apparatus by the United States Government was conducted by the Technologic Branch of the Geological Survey at the Arsenal grounds, Pittsburgh, Pa., in 1909. In 1910 the Bureau of Mines was established, and the work of the Technologic Branch of the Geological Survey, including mine rescue training, was transferred to the new bureau. Mine safety cars were used as headquarters for field instructors and engineers who, in the fall of 1910, conducted mine rescue training from these cars as well as from the field stations of the Bureau. Training in the use and care of self-contained oxygen breathing apparatus has been conducted in practically every mining field in the United States; to December 31, 1937, the Bureau of Mines had given this training to 62,262 men.

## DEVELOPMENT OF AMERICAN BREATHING APPARATUS

Before the spring of 1918 all self-contained oxygen breathing apparatus in use in this country were designed and manufactured in Europe, the types in use being the Draeger and Westphalia, made in Germany, and the Fleuss-Proto, made in England. Meanwhile, the Bureau of Mines encouraged the development of new and improved types of equipment. The first American-designed apparatus was the Gibbs, built in the spring of 1918 primarily for the use of the United States Army in France. The Bureau of Mines also obtained at this time a number of sets of the apparatus for its own use. The Paul apparatus, another American type, was perfected about the same time and manufactured for American use. On March 5, 1919, the Bureau of Mines adopted a schedule for testing self-contained oxygen breathing apparatus, and on January 15, 1920, the Gibbs and the Paul apparatus received the Bureau's formal approval. The Proto-Davis apparatus was approved on February 7, 1924, and the McCaa apparatus on August 31, 1925. The Draeger (1924 type) apparatus was approved August 1, 1929. Foreign types (Fleuss-Davis and Draeger) are not used in the United States at present. The most recent addition to the list of permissible self-contained oxygen breathing apparatus is the M.S.A. 1-hour type approved July 28, 1937.

The superiority of American types of oxygen breathing apparatus over those made in Europe is due largely to the use of improved regenerating material and the adoption of automatic admission and reducing valves.

## REGULAR MINE RESCUE TRAINING COURSE

The regular mine rescue training course of the Bureau of Mines is designed to train men in the mineral industries to prepare and test self-contained oxygen breathing apparatus for use, to maintain the equipment in safe working condition, to wear the equipment while performing hard labor with confidence in the protection it affords, and to know what to do in the event of emergency or damage to the equipment while it is being worn in irrespirable atmospheres.

The course consists of not less than 20 hours of lecture, demonstration, and practice with the apparatus. In addition to learning how to assemble and test the apparatus, those taking the course must wear it in an irrespirable atmosphere for four 2-hour periods, during which a schedule of hard labor is performed. This procedure gives the wearer confidence in the equipment that can be acquired in no other way; moreover, he becomes familiar with its limitations and learns definitely at what rate of speed he can perform labor safely.

It is customary to train men as crews rather than as individuals, a standard crew consisting of four men and a captain; actual work in mines with the use of oxygen breathing apparatus also should be by crews rather than by individuals. In addition to learning how to operate the equipment, the men are taught team organization, life-line signals, and mine rescue procedure affecting the individual team.

The men in training usually are given actual practice in wearing the apparatus in "smoke rooms" built for that purpose or in mine buildings that can be made essentially airtight to hold the fumes introduced to create an irrespirable atmosphere. In recent years the tendency has been toward conducting part of the training underground. Usually a portion of the mine is set aside temporarily for this purpose, and a hypothetical mine rescue or recovery problem is worked out by the men wearing the apparatus.

Digitized by Google Original from THE OHIO STATE UNIVERSITY

In describing the training work accomplished by the Bureau of Mines, however, it is not desired to minimize similar work of State departments of mines and of mining companies that maintain their own mine rescue stations and equipment. The latest estimate places the total number of self-contained oxygen breathing apparatus in this country at 2,260, of which 228 sets are owned by the Bureau of Mines, and the number of mine-rescue stations at 347, of which 14 are owned by the Bureau. The Bureau of Mines cooperates with State and privately owned stations, usually by giving the men initial training and by giving additional training periodically. Another service to State and privately owned mine rescue stations is a rigid and thorough inspection of and a complete report to the management on the condition of their equipment by a representative of the Bureau in connection with the training work. In recent years, owners of oxygen breathing apparatus have shown a marked tendency to allow this equipment to deteriorate. Usually this is not intentional, and when the poor condition of the equipment is brought to the attention of the proper officials, steps usually are taken to put it into proper condition for use.

## NEED FOR ADVANCED TRAINING

After the development of self-contained oxygen breathing apparatus the following additional, very useful equipment for mine rescue and recovery work was introduced: The all-service gas mask, for use in poisonous atmospheres in which there was enough oxygen to support life, the hoolamite detector for the detection of carbon monoxide; several types of methane detectors to supplement the flame safety lamp; the pyrotannic acid method for determining the percentage of saturation of carbon monoxide in blood and in air; and simplification of methods of analyzing mine air so that it became practicable to determine fairly accurately the composition of mine air in the field by use of the portable Orsat equipment. Although this equipment is available to the mining industry, it is still necessary to a certain extent to teach the industry how, when, and where to use it.

The Bureau's long experience at mine fires and explosions in nearly every mining field in the United States over many years indicated the necessity for a more complete course of training for those who are likely to be called upon to render assistance in mine disasters, and particularly for those who may have to plan and direct rescue and recovery operations. With these ideas in mind, an outline for an advanced mine rescue training course was prepared and tried out in the field during 1925.

## ADVANCED MINE RESCUE TRAINING COURSE

In testing the course in the field an effort was made to teach men who were likely to remain a permanent part of the mining organization, such as underground mining officials, mine superintendents, and inspectors--in other words, men who might be called upon to direct rescue and recovery work following mine fires and explosions. One of the additional requirements of persons desiring to take the course was that they must have certificates showing that they had been trained previously in the regular mine rescue course.

Original from THE OHIO STATE UNIVERSITY

The first trial classes were conducted in the fall of 1925 at the Orient Central mine rescue station, Orient, Fayette County, Pa., in cooperation with officials of the station and contributory companies. Fifty-seven men took the course in four classes of one week each. Following the classes at Orient, Pa., three classes were conducted at Thomas, W. Va., where 51 officials of the Davis Coal & Coke Co. and several representatives of the Departments of Mines of West Virginia and Maryland completed the course. Subsequently this course became a regular part of the work of the Safety Division of the Bureau of Mines, and to December 31, 1937, 3,183 men had taken the course and had been awarded certificates by the Bureau. The men comprising the classes consist chiefly of superintendents, mine foremen, assistant mine foremen, firebosses, safety engineers, state mine inspectors, and members of mine rescue crews. Incidentally, during 1937 all mine inspectors on the staff of the West Virginia Department of Mines have taken advanced mine rescue training.

The course consists of 40 hours of lectures, demonstrations, and practice in the use of various types of gas-detection and protective devices, and actual underground practice in mine rescue procedure in which hypothetical problems are worked. The following outline gives a comprehensive idea of the subject matter contained in the course:

## ADVANCED TRAINING IN MINE RESCUE AND RECOVERY OPERATIONS FOR COAL-MINE FIRES AND EXPLOSIONS

Introductory remarks: Need, history, safety division, lectures, and demonstrations. Equipment and practices.

1. Mine gases: Miners' Circular 33, Mine Gases and Methods for Their Detection (1937), and Bureau of Mines Gas Chart.
    - A. Sources.
    - B. Properties.
    - C. Physiological effects.

2. Methods of detecting mine gases: Miners' Circular 33, Mine Gases and Methods for Their Detection (1937).
    - A. Methane ($CH_4$).
        - (1) Approved flame safety lamps.
        - (2) Approved flame safety lamps, provided with bimetal indi-indicating device.
        - (3) Burrell indicator.
        - (4) Martienssen indicator.
        - (5) U. C. C. indicating detector.
        - (6) M. S. A. indicating detector.
    - B. Oxygen deficiency.
        - (1) Approved flame safety lamp (lamp-testing cabinet).
    - C. Carbon monoxide (CO).
        - (1) Canaries.
        - (2) Iodine pentoxide (hoolamite).
        - (3) Pyrotannic acid.

3. Sampling and analysis of mine gases: Miners' Circular 34, Sampling Mine Gases and Use of the Bureau of Mines Portable Orsat apparatus in Their Analysis (1936).
    A. Collecting samples.
        (1) Water displacement.
        (2) Aspirator bulb.
        (3) Vacuum tube.
        (4) Behind fire seals.
    B. Analyzing samples.
        (1) Laboratory apparatus and equipment.
        (2) Portable water Orsat apparatus.

4. Methods of protection against mine gases: Miners' Circular 35, Protection Against Mine Gases (1937), and Self-Contained Oxygen Breathing Apparatus Handbook (1934).
    A. Erection of barricades.
    B. Approved self-rescuer.
    C. Approved gas mask.
    D. Approved oxygen breathing apparatus.
        (1) Gibbs.
        (2) Paul.
        (3) Proto-Davis.
        (4) McCaa.
        (5) Draeger.

5. Resuscitation: Miners' Circular 35 (1937) and Manual of First Aid Instruction (1935).
    A. Schaefer method.
    B. Sylvester method.
    C. Oxygen inhaler.

6. Organization, equipment, and procedure for recovery operations: Miners' Circular 36, Procedure in Sealing and Unsealing Mine Fires and in Recovery Operations Following Mine Explosions (1938).
    A. Surface organization (organization chart).
    B. Equipment.
        (1) Oxygen breathing apparatus and gas masks.
        (2) Devices for detecting mine gases.
        (3) Instruments and material.
    C. Permissible electric lamps.
        (1) Cap lamps.
            a. Edison.
            b. Wheat.
            c. Ceag.
        (2) Eveready flashlight.
    D. Stoppings.
        (1) Temporary stoppings.
            a. Canvas.
            b. Lumber.
        (2) Permanent stoppings.
            a. Brick.
            b. Concrete block.

Original from THE OHIO STATE UNIVERSITY

        - c. Poured cement.
        - d. Plaster.
        - e. Packwall.
- E. Mine fires.
    - (1) Fighting mine fires.
    - (2) When and how to seal mine fires.
    - (3) When and how to unseal mine fires.
        - a. Recovery by air locks.
        - b. Recovery by direct ventilation.
- F. Procedure after mine explosions.
    - (1) Surface.
    - (2) Entering mine.
    - (3) Establishing fresh-air base.
    - (4) Exploring.
- G. Underground practice work.
    - (1) Before going underground.
    - (2) After going underground.
    - (3) Rules of procedure.
        - a. Life-line signals.
        - b. Before leaving fresh-air base.
        - c. After leaving fresh-air base.

The course of instruction begins with a lecture on the properties of mine gases, with particular stress on sources, explosive limits of methane and air, physiological effects, etc. The devices used in the detection of mine gases are then studied--approved types of flame safety lamps, all types of methane detectors and indicators, the hoolamite carbon monoxide detector, and the pyrotannic acid method for determining the quantity of carbon monoxide in samples of blood and of air. In addition to lectures and demonstrations on the detection of mine gases, classes are instructed regarding the different methods of air sampling, such as vacuum tube, water displacement, and aspirating bulb; the taking of samples from behind seals in fire areas; and, finally, the analysis of normal mine air. At the completion of the course, every class member is expected to make a complete analysis of air samples taken from a fire area and of normal mine air by means of the portable water Orsat apparatus.

Members of the class are not only expected to learn how to analyze air samples but they are taught also how to interpret the samples and use the interpretation as a guide in procedure work. For instance, they are taught that regions from which samples containing less than 12 percent oxygen are taken probably do not contain an explosive mixture of gas and air, regardless of the amount of explosive gas present, unless additional oxygen is admitted into the area. They learn to determine by analysis whether a region under seal contains an explosive mixture, whether it is likely to contain an explosive mixture later, or whether an explosive mixture can be produced by the introduction of air. Interpretation of samples collected from fire-sealed areas, with other data, indicates the progress of the extinguishment of the fire and the time for unsealing, a good rule being not to unseal a fire region until all traces of carbon monoxide have

Digitized by Google Original from THE OHIO STATE UNIVERSITY

disappeared from the atmosphere behind the seals; good practice also demands that some additional time be allowed for cooling. The significance of the analysis of normal mine-air samples in circulating air is interpreted by calculating the number of cubic feet of methane being produced per minute and per 24-hour period in the returns from each split and in the main returns.

After classes have been drilled thoroughly in the use of instruments for the detection of mine gases, sampling and analysis of mine gases and measures approved by the Bureau for protection against these gases are studied; these include the erection of barricades during mine fires and explosions, the use of the miner's self-rescuer and the all-service gas mask, and, finally, the use of all types of self-contained oxygen breathing apparatus. Considerable time is devoted to the proper method of constructing stoppings used in restoring ventilation after explosions and the types of stoppings used for fire seals.

Classwork not only consists of lectures and demonstrations, but class members are required to gain practical experience in the operation of the various pieces of equipment considered in the course.

That a clear idea may be gained of the correct method of conducting recovery work, 2 days of the course are spend in training crews in rescue and recovery procedure underground. Before the underground maneuvers are begun, a fire or explosion is assumed to have occurred in a certain section of a mine, the region selected usually consisting of a pair of entries and several rooms. The instructor arranges the region that is to be involved in the recovery operations before the practice work is started by marking with chalk or by placing at various points signs, such as "Explosive gas," "Carbon monoxide," "Blackdamp," "Fire," "Barricaded men," "Dead men," and "Falls." When an explosion is involved in the problem, stoppings, doors, and overcasts are marked "Blown out" to show that ventilation has been destroyed. Various other signs of force or violence are indicated by chalk marks.

Time also is devoted to instruction regarding the surface organization plan to be put into effect in case of explosions and fires. A definite emergency surface organization plan for both coal and metal mines has been worked out by engineers of the Bureau of Mines, providing for surface arrangements necessary for conducting rescue and recovery operations safely and efficiently. In this connection, it may be of interest to note that at least one large coal company has a completely developed emergency organization plan, in which every key employee has been assigned a definite post of duty to be assumed in case of emergency. To be sure that the plan is effective, emergency drills or maneuvers are held frequently, in which a fire or explosion is assumed to have occurred at one of the mines. The superintendent of the mine notifies the proper general office officials, and a general alarm is spread; while the local key employees are taking their assigned emergency posts of duty, apparatus crews are assembling at the other mines and, upon arrival at the mine in question, find a complete emergency surface organization functioning, so rescue and recovery maneuvers can proceed without delay.

The course is arranged to train leaders who can handle systematically a fire or explosion with a minimum amount of outside assistance. The company at whose mine the training is given usually provides the necessary oxygen breathing apparatus, gas masks, and supplies for conducting the work; the equipment for demonstration purposes, however, is furnished by the Bureau.

## PUBLICATIONS

After the course had been used in the field a short time, it was apparent that a published text was needed to supplement the class instruction and to be used for reference and study by those completing the class work. Four circulars were compiled for this purpose and issued by the Bureau as Miners' Circulars 33, 34, 35, and 36. The preparation of these circulars was completed during 1928 and 1929, and they were published in 1929; they were revised and brought up to date in 1936, 1937, and 1938.

Miners' Circular 33, "Mine Gases and Methods for Their Detection", discusses in detail the character and occurrence of gases likely to be encountered in mines and methods for their detection, including the flame safety lamp and its misuse; all types of methane detectors; the detection of carbon monoxide by the iodine pentoxide indicator and the use of small animals and birds; and the quantitative determination of carbon monoxide in blood and air by the pyrotannic acid method. Incidentally, because of its accuracy in small percentages, the last method is invaluable in making carbon monoxide determinations from samples collected from behind sealed areas. The hydrogen sulphide detector also is described. Information Circular 6983, "Some Pertinent Information About Mine Gases", also is useful in presenting information on the subject of gas hazards in mines.

Miners' Circular 34, "Sampling Mine Gases and Use of the Bureau of Mines Portable Orsat Apparatus in Their Analysis", considers in detail various methods of collecting mine-air samples under normal mine conditions, at explosions, and from behind fire seals, and gives the step-by-step procedure in analyzing these samples by the water Orsat apparatus. The instructions are so complete that anyone with a knowledge of simple arithmetic can learn to determine the quantity of methane, carbon dioxide, carbon monoxide, oxygen, and nitrogen in a sample, with the limits of accuracy of the Orsat.

Miners' Circular 35, "Protection Against Mine Gases", discusses the erection of barricades during mine fires or following mine explosions, the construction of refuge chambers, the use of the carbon monoxide self-rescuer, gas masks, oxygen breathing apparatus, and resuscitation. Its object is to acquaint men thoroughly with the various methods and devices used for protection against mine gases.

Miners' Circular 36, "Procedure in Sealing and Unsealing Mine Fires and in Recovery Operations Following Mine Explosions", discusses organization, equipment, materials used, and procedure in fighting, sealing, and unsealing mine fires and in recovery operations following explosions; a practice problem for recovery procedure also is included. Although the

Digitized by Google Original from THE OHIO STATE UNIVERSITY

data contained in this publication relate primarily to comparatively thin or medium thick coal beds with little if any pitch, it is believed that the procedure for sealing and unsealing mine fires, with the principle and technique of identifying fire gases, is applicable in some degree and with some modifications to metal mines and to coal beds (thick or thin) with varying pitches.

## MINE EXPLOSIONS IN THE UNITED STATES

Progress in the development of methods, equipment, and education for mine rescue and recovery work during the past few years has aided materially in handling mine explosions and in reducing the fatalities resulting therefrom. The record of fatalities from mine explosions in the United States during the 3 years 1934-36 has been the best in the history of the mining industry. During these 3 years mine explosions have resulted in an average of 40 deaths per year, compared with an average of 153 deaths per year for the preceding 5 years and a yearly average of 265 deaths for the 20-year period prior to 1929. Incidentally an average of 542 deaths per year resulted from mine explosions during the 3 years 1907-1909, inclusive, just before the organization of the Bureau of Mines.

The fact that there has been a substantial reduction in the number of widespread mine disasters has produced a marked tendency to neglect the training of new men to take the place of the former experienced rescue men; moreover, some owners of mine rescue equipment have allowed their equipment to deteriorate until it is worse than useless. The lack of experienced mine rescue men has been felt already in some sections as is evidenced by the fact that the Mine Inspectors Institute of America has a committee working on the problem of how new men can obtain practical underground mine rescue and recovery experience under actual conditions similar to those encountered at mine fires and explosions.

## CONCLUSIONS

The technique of combating mine fires and explosions has improved immeasurably during the past 30 years. In almost all cases mine fires can be extinguished successfully, and recovery operations can be carried on with little risk to life, provided a systematic procedure is followed and modern means are employed for detection of and protection against mine gases. There is, however, definite need for more education along these lines, and we believe that the Bureau of Mines Advanced Mine Rescue Training Course fulfills much if not all of this requirement.

## ACKNOWLEDGMENTS

The writer wishes to acknowledge the assistance of G. W. Grove, mining engineer, and M. J. Ankeny, associate mining engineer, of the Bureau of Mines, in the preparation of this paper.